Eur J Vasc Endovasc Surg (2010) **39**, 714–718

Abdominal Aortic Doppler Waveform in Patients with Aorto-iliac Disease

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Submitted 15 November 2009; accepted 31 January 2010
Available online 1 March 2010

KEYWORDS
Mid-systolic deceleration;
Doppler;
Abdominal aorta;
Aorto-iliac disease

Abstract *Objectives:* The mid-systolic deceleration (notch) in the proximal descending aortic Doppler waveform was reported to be common in patients with aorto-iliac disease. However, evaluation of the descending aorta is limited to echocardiography and may be technically difficult. Therefore, we decided to check whether similar Doppler flow disturbance can be found in abdominal aorta, which is easily evaluated in wider range of patients undergoing general abdominal and vascular ultrasound, as well as echocardiography.
Methods: We evaluated 115 consecutive symptomatic patients with severe peripheral artery disease admitted for vascular surgery, and 60 controls. The presence or absence of the mid-systolic deceleration in the Doppler waveform was evaluated retrospectively, by the single echocardiographer blinded to the localisation of the arterial occlusion or stenosis.
Results: The mid-systolic notch in the proximal abdominal aorta was present in 58 of 71 patients (82%) with significant aorto-iliac disease, seven of 44 (16%) patients with occlusion or significant stenosis distally to the external iliac artery ($P < 0.001$) and in none of the patients from the control group. Sensitivity, specificity and positive predictive value of the mid-systolic notch in the abdominal aortic Doppler waveform in the detection of aorto-iliac disease in patients with peripheral artery disease were 82%, 84% and 89%, respectively.
Conclusion: The mid-systolic deceleration (notch) in the proximal abdominal Doppler waveform is a simple ultrasonographic marker of significant aorto-iliac disease.

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1078-5884/$36
doi:10.1016/j.ejvs.2010.01.026

Ultrasonographic assessment of the distal aorta and the iliac arteries is frequently difficult due to the deep course of these vessels. There were attempts to evaluate aorto-iliac segment indirectly, by analysing Doppler waveform in easily accessible common femoral artery. However, the diagnostic value of this method significantly differed between studies.[1–3] It has recently been demonstrated that patients with occlusion or significant stenosis in aorto-iliac segment have abnormal Doppler waveform in the proximal descending aorta.[4] It consisted of mid-systolic deceleration (notch), possibly resulting from a high-amplitude pressure wave reflected from occlusion or significant stenosis sites in aorto-iliac segment.

Evaluation of the descending aorta may be limited by the difficulties in visualisation, potential distortion of flow by aortic arch curvature and a need for a cardiac sector probe. However, proximal abdominal aorta is easily accessible for echocardiographers, vascular and general sonographers, thus increasing the number of patients eligible for evaluation. Therefore, we decided to check whether analysis of abdominal aortic Doppler waveform may be useful in the detection of aorto-iliac disease.

Materials and Methods

Patients

We evaluated 133 consecutive symptomatic patients with severe peripheral artery disease (PAD) admitted for vascular surgery, who had recorded abdominal Doppler flow during echocardiography. Eighteen patients (14%) were excluded due to suboptimal visualisation of proximal abdominal aorta and poor quality of Doppler waveform; therefore, 115 patients were included in the final analysis. Most of the patients with PAD had classic risk factors for atherosclerosis and were treated with various vasoactive drugs, including anti-hypertensives and statins. The characteristics of the patients are presented in Table 1 and the methods of treatment in Table 2. Significant proximal PAD was defined as an occlusion or ≥70% stenosis in the abdominal aorta, common iliac or external iliac artery. The control group consisted of 60 asymptomatic patients with treated hypertension (mean age 63.5 ± 10 years, 55% women) with ankle–brachial index (ABI) > 0.9 referred for echocardiography from an ambulatory clinic.

Aortic evaluation

Echocardiographic examination was ordered by a surgeon or an anaesthesiologist as a part of perioperative risk assessment. The study was performed in a non-fasting state, usually 2–3 h after breakfast. Abdominal Doppler flow was recorded (Vivid 5, Echopac, GE>) from the subcostal view, in a supine position at the end of echocardiographic examination, as a duplex Doppler imaging, with 2.5 MHz sector probe and sweep speed of 50 mm s^{-1}. A Doppler gate was placed in the aortic segment between diaphragm and celiac trunk, depending on the optimal acoustic window. Care was taken to achieve a Doppler angle of <60°. The echocardiographic study and aortic Doppler waveform recordings were performed by a single experienced echocardiographer; and the presence or absence of the mid-systolic deceleration in the Doppler waveform (Fig. 1) was evaluated retrospectively by another single experienced echocardiographer. Both physicians were blinded to the localisation of the arterial occlusion or stenosis. The level of obstruction or significant (≥70%) stenosis was assessed based on the reports from computed tomography (CT) angiography.

Table 1 Characteristics of the patients with peripheral artery disease (PAD).

Variable	Proximal PAD (*n* = 71)	Distal PAD (*n* = 44)	*p*
Age (years)	64 ± 10	66 ± 11	Ns
Women	30 (42%)	9 (20%)	0.06
ABI	0.5 ± 0.2	0.59 ± 0.2	Ns
Fontaine classification			
Stage I	0 (0%)	0 (0%)	Ns
Stage IIa	1 (2%)	2 (5%)	Ns
Stage IIb	28 (39%)	9 (20%)	Ns
Stage III	30 (42%)	16 (36%)	Ns
Stage IV	12 (17%)	17 (39%)	0.03
BMI (kg/m^2)	24 ± 3	26 ± 5	0.01
SBP (mmHg)	138 ± 23	139 ± 22	Ns
DBP (mmHg)	72 ± 12	76 ± 11	Ns
Heart rate (1/min)	72 ± 14	70 ± 10	Ns
LVMI (g/m^2)	117 ± 27	118 ± 27	Ns
LVEF (%)	60 (40–70)	60 (35–70)	Ns

ABI; ankle-brachial index, BMI; body mass index, SBP; systolic blood pressure, DBP; diastolic blood pressure, LVMI; left ventricular mass index, LVEF; left ventricular ejection fraction. Values are means ± SD, except for LVEF where values are median (range).

Statistical Analysis

Sensitivity was calculated based on the following formulas: number of true positive cases (i.e., cases with mid-systolic

Table 2 Treatment of patients with peripheral artery disease (the numbers of procedures are not equal to the numbers of patients, as some of patients had multiple procedures).

Treatment	Proximal PAD (*n* = 71)	Distal PAD (*n* = 44)
Thrombendarterectomy	15	13
Aorto-femoral bypass	26	1
Ilio-femoral bypass	12	1
Percutaneous angioplasty with stent	10	5
Femoro-popliteal bypass	0	11
Lumbar sympathectomy	1	4
Amputation	6	9
Conservative	4	4
Perioperative death	5	0

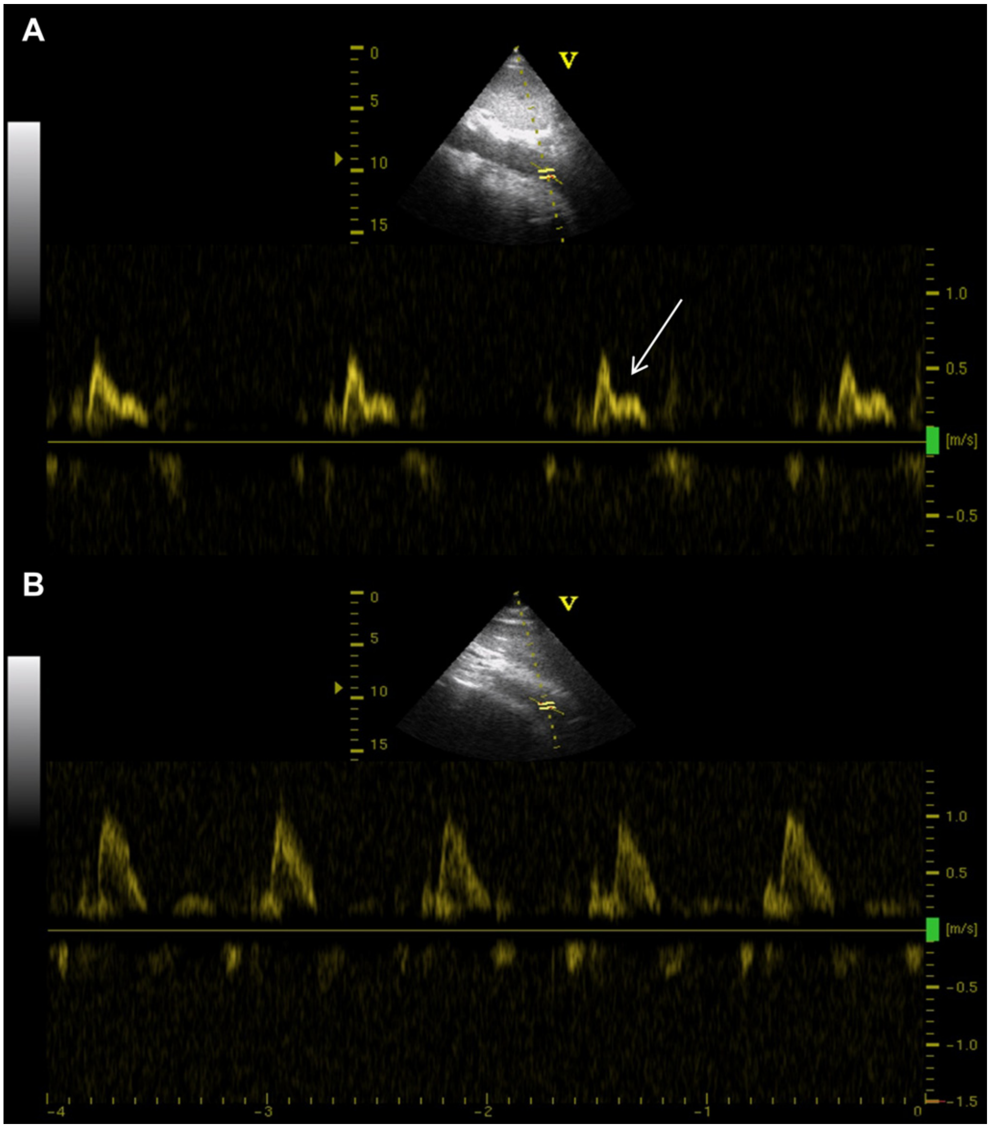

Figure 1 Proximal abdominal aortic waveform. Panel A — mid-systolic deceleration (arrow) in patient with aorto-iliac disease. Panel B — normal waveform seen in patients with occlusion or significant stenosis distally to external iliac artery and in control patients without peripheral artery disease.

notch in patients with aorto-iliac disease)/number of true positive + false-negative cases (i.e., cases without mid-systolic notch in patients with aorto-iliac disease). Specificity was calculated as a number of true negative cases (i.e., cases without mid-systolic notch in patients without aorto-iliac disease)/number of true negative + false positive cases (i.e., cases with mid-systolic notch in patients without aorto-iliac disease). Positive predictive value was calculated as a number of true positive cases/number of true positive + false positive cases. Inter-observer agreement on the presence of notch was evaluated with kappa statistics (kappa = (observed agreement − chance agreement)/(1 − chance agreement)), based on the assessment of the first 73 consecutive patients by two echocardiographers. Statistical analysis was performed using Statistica 6 software (StatSoft, USA). Continuous variables with normal distribution are presented as mean ± standard deviation, and continuous variables with non-normal distribution are presented as median (range). Student's *t*-test was used for comparison of continuous variables with normal distribution and Mann—Whitney *U*-test for comparison of continuous variables with non-normal distribution. Fisher's exact test was used for comparison of categorical variables between groups of patients. The study was accepted by the local Ethics Committee and patients gave informed consent for echocardiographic examination.

Results

Out of the 115 patients eligible for analysis, 71 had occlusion or significant (≥70%) stenosis in the aorto-iliac segment and 44 had occlusion or significant stenosis distally to the external iliac artery. Among 71 patients with proximal PAD, 31 patients (44%) had distal aortic occlusion or bilateral iliac disease.

Mid-systolic notch in the proximal abdominal aortic flow was present in 58 of 71 patients (82%) with significant stenosis or occlusion in the aorto-iliac segment, seven of 44 patients (16%) with significant stenosis or occlusion distally to external iliac artery ($P < 0.001$) and in no patient from the control group. Sensitivity of the mid-systolic notch in the detection of aorto-iliac disease in all patients with PAD was 82% and specificity 84%. Positive predictive value of mid-systolic notch in this group was 89%, and negative predictive value was 74%. In patients with distal aortic or bilateral iliac occlusion, sensitivity of mid-systolic notch in the detection of aorto-iliac disease was 93% compared to 73% in patients with unilateral iliac disease. There were 13 cases of dilatation of abdominal aorta (diameter >3 cm) co-existing with arterial stenosis. In 10 patients with aortic dilatation and significant iliac stenosis, eight patients had mid-systolic notch on Doppler evaluation, and in three patients with aortic dilatation and no significant iliac stenosis, mid-systolic notch was absent. The inter-observer agreement on the diagnosis of mid-systolic notch was good with κ value equal to 0.7.

Discussion

Results of this study show that mid-systolic notch in the Doppler spectrum in proximal abdominal aorta may be a simple, non-invasive indicator of proximal PAD, and may represent an additional tool for indirect assessment of the aorto-iliac segment. Our findings may be easily implemented in the clinical practice, because the proximal part of the abdominal aorta can be visualised by ultrasonography in most of patients, using both cardiac sector and abdominal convex probes. Evaluation of this part of the aorta is routinely performed during general abdominal and vascular ultrasound and may be also a useful addition to a routine echocardiographic study. In a cardiac patient, this simple and short extension of echocardiographic examination may give clinically useful information not only about the extent of atherosclerotic disease, but it may also influence the choice of vascular access in case of planned percutaneous interventions.

The experimental studies and previous clinical observations suggest that the mid-systolic deceleration of flow in the aorta results from a high-amplitude backward pressure wave, reflected from occlusion or stenotic sites near aortic bifurcation.[4–6] Timing of the return of the pressure wave is influenced mainly by the distance to the occlusion and wave velocity.[5,7] With the similar distance to the occlusion, factors that increase wave velocity (e.g., increased wall stiffness, elderly age, increased blood pressure, increased heart rate, decreased arterial diameter and lower blood density) will move the time of return of the reflected pressure wave more into systolic phase of flow, resulting in the mid-systolic deceleration. Conversely, slowing of the wave velocity will move return of the reflected wave into diastolic phase, resulting in the absence of mid-systolic notch.[7–9] This may explain false positive and false-negative results in some of our patients with proximal PAD. We speculate that the lack of mid-systolic notch in majority of patients with distal PAD is probably due to lower amplitude of the reflected pressure wave and/or increased distance to the occlusion. Although the normal waveform was present in both distal PAD and healthy controls, the finding of the mid-systolic notch was specific for PAD (it was absent in all patients from the control group). However, due to relatively small number of control patients, its clinical value should be tested on a larger unselected population.

Limitations

The majority of our patients presented with severe symptoms of arterial ischaemia. Most of them had occlusions rather than stenosis in aorto-iliac segments, and substantial proportion had distal aortic occlusion or bilateral iliac disease. Whether our findings would apply to the population of less-advanced aorto-iliac disease is not known. Most of our patients were on vasoactive drugs that could influence pulse wave velocity and thus timing of the arrival of the reflected pressure wave. The pharmacologic treatment was however similarly distributed among studied groups of patients. In most of our patients, evaluation of aortic Doppler waveform was performed with cardiac sector probe with presets used in echocardiography. It is unlikely that the use of convex probe with abdominal presets would change the shape of the waveform. In a subset of 10 patients evaluated with both probes and presets, the analysis of the Doppler waveform gave similar results regarding the presence or absence of mid-systolic deceleration. The diameter of the abdominal aorta was not routinely measured by ultrasound and was not included in CT reports except in the cases of aortic dilatation. Based on the results from this study, in our opinion, the presence of abdominal aortic dilatation did not influence the results.

In conclusion, mid-systolic deceleration (notch) in the proximal abdominal aortic Doppler waveform is common in patients with occlusion or significant stenosis in aorto-iliac segment. It may be a simple ultrasonographic marker of the significant aorto-iliac involvement.

Conflict of Interest

None.

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